ARKIV FÖR FYSIK Band 17 nr 31

Communicated 27 January 1960 by M. SIEGBAHN

The empirical matrix element of the $M4$ transition in Xe^{135}

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With 8 figures in the text

ABSTRACT

The M4 transition in Xe^{135} has been investigated by use of electromagnetically isotope separated samples. The measured energy of the transition is 527.4 ± 0.8 keV and the half-life 15.8 ± 0.4 min. The empirical matrix element of the $M4$ transition is found to be equal, within the experimental errors, to those of the other known $M4$ isomers in Xe, except Xe^{129m}.

Introduction

The purpose of the following is to discuss an investigation of the decay of Xe^{135m}, which has been undertaken with special emphasis on those factors which are essential in determining the experimental matrix element of the $M4$ transition. These factors are mainly (*a*) the half-life of the isomeric level, (*b*) competing transitions to the $M4$ electromagnetic radiation such as β-branching and (*c*) the energy of the $M4$ γ-ray. It is of special importance to know the energy to a high accuracy as the empirical matrix element depends to the ninth power on the energy in the case of an $M4$ transition [1, 2].

A comparison of the magnitudes of the experimental matrix elements of the $M4$ type of a given element has shown the interesting fact that these are in some cases constant within the experimental errors, which are about 10 % in the best known cases, namely those in Pb [3]. This is in contradiction to what one would expect from the theoretical point of view, which would rather indicate that the matrix elements should increase when approaching a closed shell as one then should have purer single particle transitions [2]. This statement is, however, grounded on qualitative calculations and it is therefore difficult to know the magnitude of the increasing factor. This was, however, considered to give a larger difference between the matrix elements than 10 %. It seems, however, possible to obtain a more quantitative estimation of the effect. Recently, for example, K. K. Gupta and R. D. Lawsen [4] have investigated the effect of weak configuration mixing on magnetic multipole radiation with emphasis on the $M4$ transition. They have taken into consideration only nuclei having a single particle or hole outside a closed shell for which relatively pure single-particle configuration can be assumed. No more thorough conclusion can therefore be obtained from that work. An extension of the calculation considering the effect discussed in this paper seems, however, possible.

The experimental values of the $M4$ transition from isomeric levels in elements around the double closed shells with $Z = 82$ and $N = 126$ have recently been summarized by I. Bergström and G. Anderson [5]. There it is clearly indicated that the matrix elements of the $M4$ transitions in Pb are nearly constant. For other elements in this region no such obvious constancy is seen. For transitions of the type $g_{9/2} \rightleftharpoons p_{1/2}$ not so many cases of each element are known, which makes a comparison more difficult. On the other hand in the second islands of $M4$ isomers namely those in the vicinity of $Z = 50$ and $N = 82$ a larger number is known. However, $M4$ transitions in the element (Sn) closest to the doubly filled shell are rare. Only two $h_{11/2} \rightarrow d_{3/2}$ transitions are known namely those with $N = 67$ and 69 [cf. e.g. 6, 7]. It can, however, be mentioned here that a study of Sn isotopes, obtained in U-fission and prepared by electromagnetic isotope separation has recently shown that there exist relatively long lived activities with half-lives of the order of hours in mass numbers 131 and 129 [8]. These are probably due to $M4$ isomers in those isotopes.

For the isomeric transitions in the other elements Te, Xe, Ba and Ce it has been shown [7] that the matrix elements of the transitions are roughly constant within the experimental errors. In Xe and Ba a small tendency for the value of M^2 to increase close to a filled shell is observed. However, in Xe the case closest to the magic number $N = 82$, namely $Xe^{135\,m}$, showed a relatively large uncertainty of the matrix element, which made an investigation of this isotope of interest. Especially the energy of the $M4$ γ-ray had a large error.

In the following, besides the description of the measurements of the different components of the empirical matrix element a detailed discussion is given of the preparation of the sample made by electromagnetic isotope separation, because in some details the procedure used is not common. Lastly a comparison between the different values of the matrix elements for the Xe-isomers is made.

Experimental procedure and results

$Xe^{135\,m}$ was obtained as a product in neutron fission of U^{235}. As the short half-life of the $h_{11/2}$ level in Xe^{135} ($T_{1/2} \approx 15$ min) made it impractical to study its decay from the activity produced directly, it was necessary to milk the desired activity from its mother substance I^{135}, which has a longer half-life ($T_{1/2} \approx 6.7$ hr). The decay chain $I^{135} \rightarrow Xe^{135} \rightarrow Cs^{135} \rightarrow Ba^{135}$ as given in the Nuclear Data Sheets [10] is seen in Fig. 1. Not very much is known of the decay of I^{135}. It has been shown, however, that about 30 % of the decay feeds the isomeric state, while the rest populates the ground state, of Xe^{135}. Only scintillation spectroscopy has been applied in determining decay characteristics including the energy of the isomeric transition of Xe^{135}. Recently some more information, such as a large number of newly detected γ-transitions, has been reported [10], but it has not been possible to incorporate these in Fig. 1. The decay of Xe^{135}, on the other hand, has been carefully studied [6, 10]. This made it easier to investigate a possible β-branch from the $h_{11/2}$ level in Xe^{135}.

Source preparation

Uranyl nitrate was irradiated in the Swedish reactor R1 for about 15 hr (flux $= 3 \cdot 10^{12}$ neutr/cm$^2 \cdot$s). The chemical separation to obtain carrier-free iodine from the fission products consisted of a simple distillation method. The irradiated $UO_2(NO_3)_2 \cdot 6\ H_2O$ was dissolved in water and fumed together with a few cc of H_2O_2 and

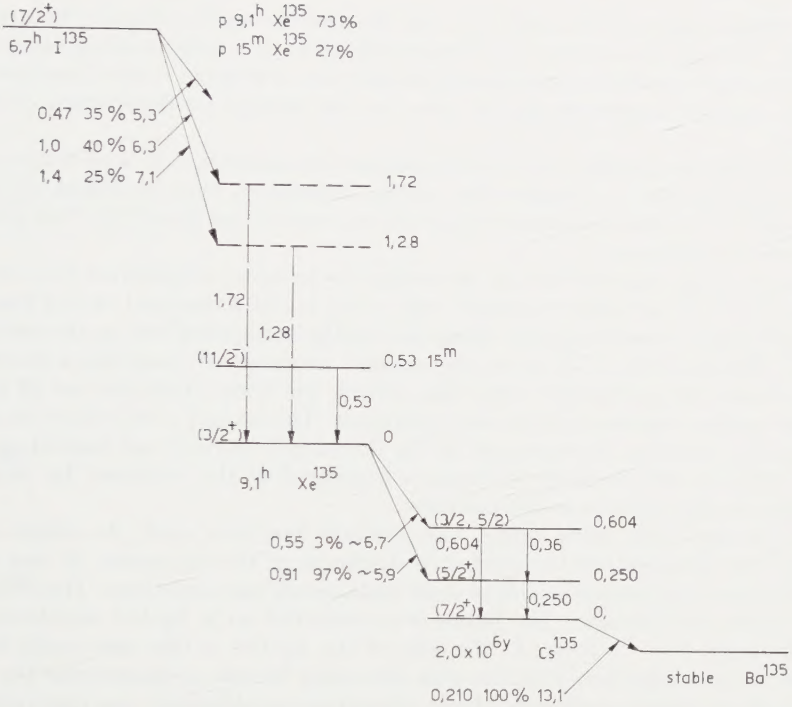

Fig. 1. The decay chain $I^{135}\rightarrow Xe^{135}\rightarrow Cs^{135}\rightarrow Ba^{135}$. From [10].

H_2SO_4. The distillation product was collected in a solution containing 0.5 N NaOH and a small amount of Na HSO_3. The separation time required to obtain a reasonable amount of activity was about half an hour.

The electromagnetic isotope separator used in this investigation is of the "low intensity" type [9]. This means that the current usuable in the instrument is of the order of 10–50 μA, while the resolving power obtainable is roughly 1000–2000. The efficiency measured as the ratio between the collected material and the amount put into the ion source of the separator of a certain isotope is for easily separated substances about 5–10 %. In the present case the isotope separation procedure followed two different lines, according to which kind of measurements the sample was to be used for.

(A) For precision measurements of the energy of the $M4$ transition it was first thought suitable to use a sample prepared directly from the carrier-free iodine solution without isotope separation and without first specially separate Xe, because of the short half-life of Xe^{135m}. The iodine was therefore collected on an Ag-foil by simply dipping this into the solution for a short time. No other procedure was carried out. The collection efficiency for this preparation method is low, about 10 %, but as the fission yield is high for mass number 135 this was no problem. However, when the sample was used in the β-spectrometer it was soon recognized that the Xe^{135} formed in the decay of iodine easily diffused from the source, which made a measurement impossible. To hinder the escape, a thin mylar film was placed over the sample. This improved the situation, but the conditions for measurement were still imperfect. Further, as a conversion electron line due to a neighbouring iodine isotope appeared to have about the same energy as the case of interest it was found necessary to use an isotope separated sample even for the energy determination of the $M4$ transition.

When isotope separating carrier-free radioactive material it is sometimes possible to use a method which decreases the isotope separation time considerably in comparison with the normal separation time, which is about one hour [11]. This procedure is in short the following.

To the discharge chamber in the ion source of the isotope separator two ovens can be connected. One of these is charged with a few mg of a material, which has shown similar properties concerning the discharge condition required etc. as the radioactive material. The quantity, 1–5 mg, is the amount necessary to maintain a discharge in the ion source for a relatively long time, about one hour. With the use of the first oven the isotope separator is put into operation. The second oven, which is charged only with the activity, is connected to the discharge chamber and heated up at the moment when a well focused ion beam is registered at the collector. In this way a separation can be made in a few minutes.

In the present case, with iodine, this method has been used. As iodine needs a relatively low temperature to maintain a discharge in the ion source, it was possible to use Xe-gas as the help material to start and operate the separator. This facilitated the procedure in this case. The iodine was collected on a Ag-foil which served as charge material in a Pt-oven. As the area of the Ag-foil in this case could be made rather large in comparison with the area necessary for the preparation of the sample for the β-spectrometer mentioned above, the collection efficiency was relatively satisfactory. The Pt-oven was heated to about 500°. At this temperature all activity had left the Ag-foil. Fig. 2 gives a diagram of the rate at which the activity reaches the collector as a function of time and temperature of the Pt-oven (t_u in Fig. 2). These data are obtained with a test activity, I^{131}.

The heating of the oven was started a few seconds after the Pt-oven had reached the discharge chamber. Maximum effect was given to the oven which means that a temperature of 1000°C can be reached in about 10 min. It is seen in Fig. 2 that at roughly 250°C the collection of the activity has started. The whole separation is then finished in less than one minute. This is shorter than what is obtainable with a substance, as for example Pb [11], which needs a higher temperature of the ion source. This can be explained by assuming that a certain part of the lead for a certain time is condensed on the walls of the discharge chamber. This should therefore give a delay of the collection time.

The efficiency of this separation, measured as the ratio between the collected activity and the activity in the Pt-oven before the separation, was about 3 %.

Fig. 3 shows an intensity distribution in semilog scale of separated I^{131} performed by the short time procedure discussed above. This therefore gives approximately the momentary intensity distribution. This can also be obtained by a special arrangement consisting of an oscillating probe in the beam at the collector from which the signals can be fed to and registered on an oscilloscope [9]. With this it is, however, usually only possible to follow the intensity decrease to a factor of about 100 below the peak intensity. To study those effects which especially contribute to the tails of the mass lines, a more sensitive method is necessary, as for example the tracer technique shown here. This gives, of course, also the integral intensity distribution one really has in a

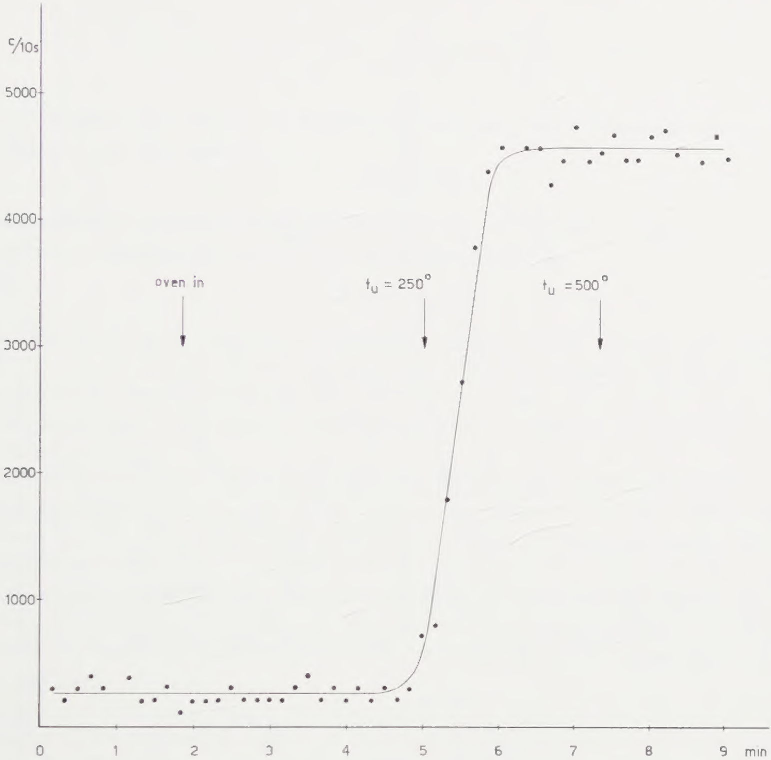

Fig. 2. Test separation of I^{131}. The activity from the collector plate versus time, showing the temperature of the ion source oven (t_u) and the separation time necessary for preparation of iodine samples.

separation, which the oscillating probe does not give. A study of the background by activity separation has been made somewhat earlier [cf. 9] but to obtain a reasonable amount of activity, a separation time of several minutes was usually necessary, which means that fluctuations in the beam intensity could disturb the measurements. With the rapid separating technique used here this can be avoided to a large extent.

The intensity distribution in Fig. 3 is obtained for an accelerating voltage of 40 kV, an ion current to the collector (Xe-current) of 10 μA and a gas pressure in the main vacuum system of $4 \cdot 10^{-6}$ mm Hg. The resolving power defined from the half-width of the mass time was about 2300 which corresponds to a half-width cf 0.75 mm. The activity was collected on an Al-foil. This was then cut into 5 mm strips on which the acitivity was counted in a scintillation spectrometer, which was set onto the 360 keV γ-ray in the decay of I^{131}. In the vicinity of the 131 mass line the activity on 0.5 mm strips was counted. The activity obtained per 0.5 mm is given in the figure as a fraction of the peak-height intensity. The peak at mass number 132 is due to HI. The existence of this is usually a complication but in the present case it can serve as a good illustration. On the other hand it can be observed that at mass number 130 a background of only 0.04% is present. Fig. 3 shows also that a few mass numbers away from 131 the activity is roughly constant. This should probably be due to gas scattering, which can give a nearly constant background within a narrow

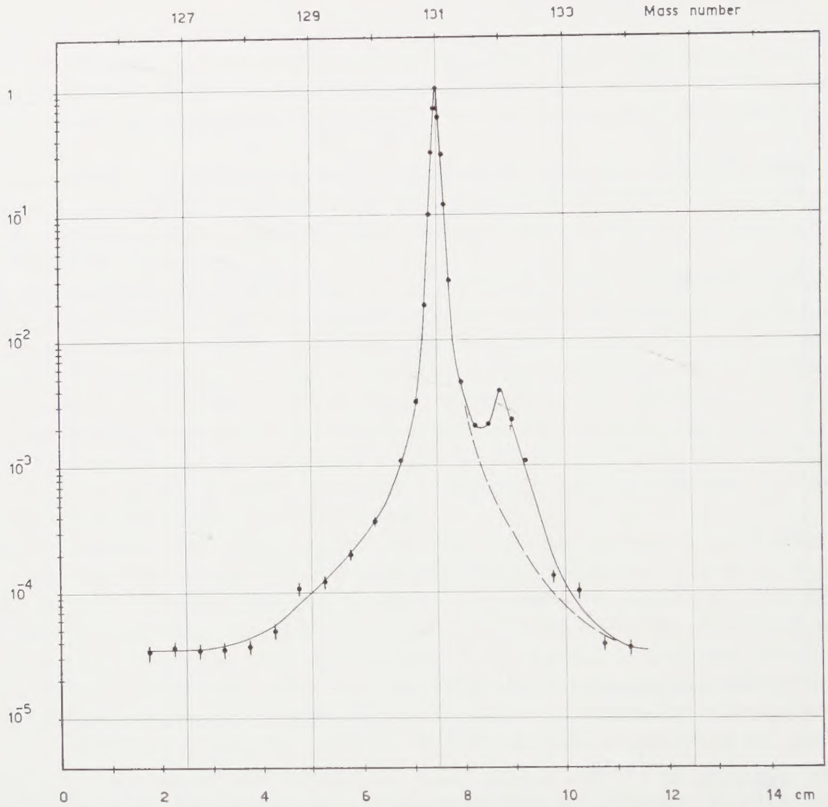

Fig. 3. Intensity distribution in semi-log scale of isotope separated I^{131} obtained in a "short time" separation. Cf. Fig. 2. The activity on mass number 132 is HI. The separation factor for a possible activity on mass number 130 is about 2500 in this case. See text.

mass region. The figures obtained from Fig. 3 are a factor of 5–10 better than those obtained earlier [9] in a long time separation. The improved conditions must to a large degree be ascribed to the decreased separating time.

To compare these figures with other similar data it is suitable to introduce the separation factor F. For a certain isotope with mass number M, $F = \frac{c_f(1-c_0)}{c_0(1-c_f)}$ where c_f is the final abundance and c_0 the initial abundance of the particular isotope. In the simplest case, when only two masses M and $M+1$, with abundance a_M and a_{M+1} are present, $c_0/(1-c_0)$ is a_M/a_{M+1}. If now the line shape of the mass lines can be approximated to be triangular with a half-width of B and if the collection is performed within a slit of magnitude S, $c_f/(1-c_f)$ is the ratio between the material (A_M) of mass number M collected within S and the contribution (A_{M+1}) from $M+1$ within S. The amount A_M is proportional to $i \cdot a_M \cdot S/B(1-S/4B)$, where i represents the total collector current of M and $M+1$, while A_{M+1} is proportional to $i \cdot a_{M+1} \cdot I \cdot$ $\cdot S(1-\delta/4B)\,\delta/B$ where I is the value on mass number M given in Fig. 3 and δ the width of the measuring slit used to obtain Fig. 3. Therefore when only one disturbing mass is present one finds

$$F = \frac{1}{I\delta}\left(1 - \frac{S}{4B}\right)\left(1 - \frac{\delta}{4B}\right)^{-1}. \tag{1}$$

In the present case with $I = 0.0004$ per 0.5 mm one obtains for mass number 130 if S is choosen to be equal δ

$$F \approx 2500.$$

Further, as the constant background seems to give a value $I \approx 3.5 \cdot 10^{-5}$ per 0.5 mm, the maximum separating factor $F_{\max}$ is according to (1),

$$F_{\max} \approx 3 \cdot 10^{4},$$

a value which is often quite satisfactory. When other masses are present these also give contributions to the background and the separation factor is therefore often somewhat less than the figures given above. As a comparison it can, however, be mentioned that "calutrons" have a separation factor of about 50 in the mass region discussed here [20].

(B) For investigations of the half-life, β-branching etc. of the isomeric state it was necessary to have a sample free from iodine. To obtain this the iodine-solution was introduced into a glass container and frozen. After evacuation some stable Xe-gas was introduced. The glass container was then shaken for about 15 min. after which the solution was again frozen and the inactive Xe-gas together with the Xe^{135} was fed to the ion source of the isotope separator. A rapid separation of about 10 min. then made it possible to prepare a suitable sample. This procedure is similar to earlier practice [cf. e.g. 12, 13].

A second method was, however, also tried. This utilized the fact that Xe obtained from iodine diffused from a Ag-foil which had iodine deposited on it in the way mentioned above. The method made it possible to obtain a very small volume containing the activity, but in the present case no other advantages over the first discussed procedure were found.

Half-life and β branching

Fig. 4 shows a scintillation spectrum obtained with a sample of type (B) and a 100-channel pulse-height analyzer of the Hutchinson-Scarrott type [14]. The curves with filled points are obtained with a new separated sample while the curves with open points are taken about 2 hours later. Fig. 4*A* gives the X-ray peak and the 250 keV peak, which is due to the decay of the 9h Xe^{135}. Fig. 4*B* shows the high energy part of the spectrum, where the peak 527 keV should correspond to the $M4$ transition. The energy given is obtained from measurements in a β-spectrometer (see later). The energy found from the γ measurements is (530 ± 6) keV. The decay of the 527 keV peak was followed for several half-lives in a single-channel pulse height analyzer. The result of such a measurement is seen in Fig. 5. The half-life ($T_{1/2}$) was found to be

$$T_{1/2} = 15.8 \pm 0.4 \text{ min}.$$

This is in accordance with earlier measurements [6, 10]. From γ-scintillation studies an estimation of the K conversion coefficient α_K was also possible. After a correction for the X-ray corresponding to the 250 kev peak, absorption and efficiency of the crystal etc., the value of α_K for the 527 kev line is found to $\alpha_K = 0.21 \pm 0.05$. This value indicates an $M4$ transition, which was also obtained in earlier investigations [6, 10].

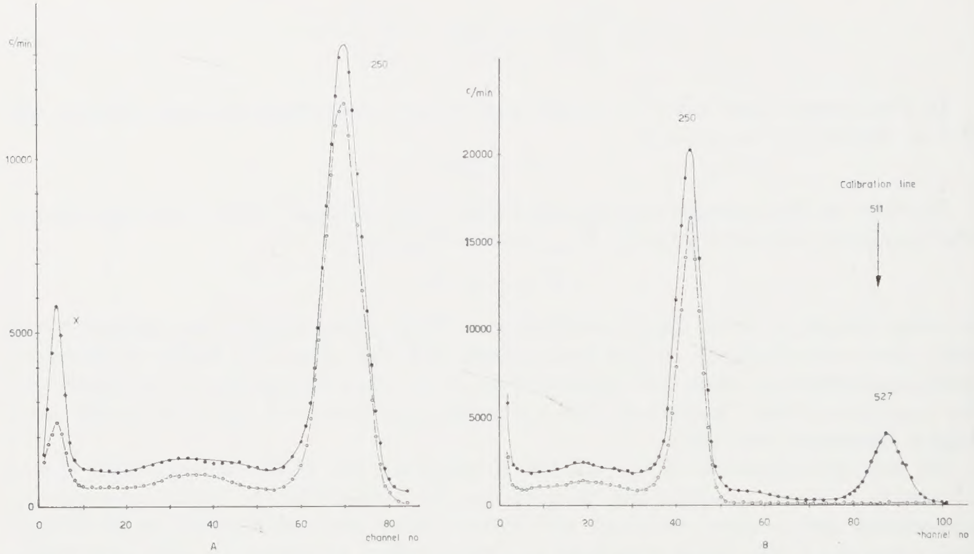

Fig. 4. Scintillation spectrum of Xe^{135m} and Xe^{135}. The curves with filled points are taken about 5 min. (Fig. 4 B) and 10 min. (Fig. 4 A) after the isotope separation procedure is finished, while the curves with open points are measured about 2 hours later.

The spectrum in Fig. 4 was also measured in order to investigate if any fast decaying component other than the 527 keV γ-ray appeared. However, no such component was found. From this one could state that a β-branching, if existing, must decay to the ground state in Cs^{135} or be followed by low energy γ-rays. The maximum

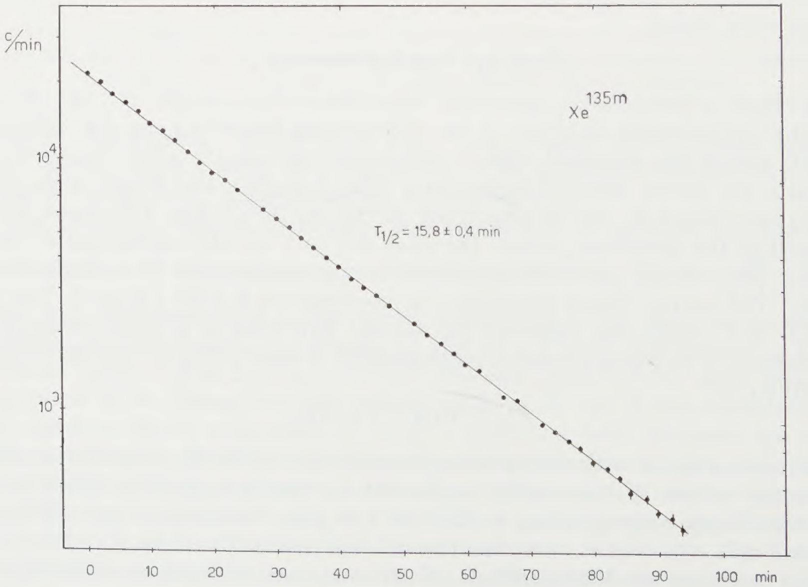

Fig. 5. Half-life of separated Xe^{135m} measured in a scintillation spectrometer.

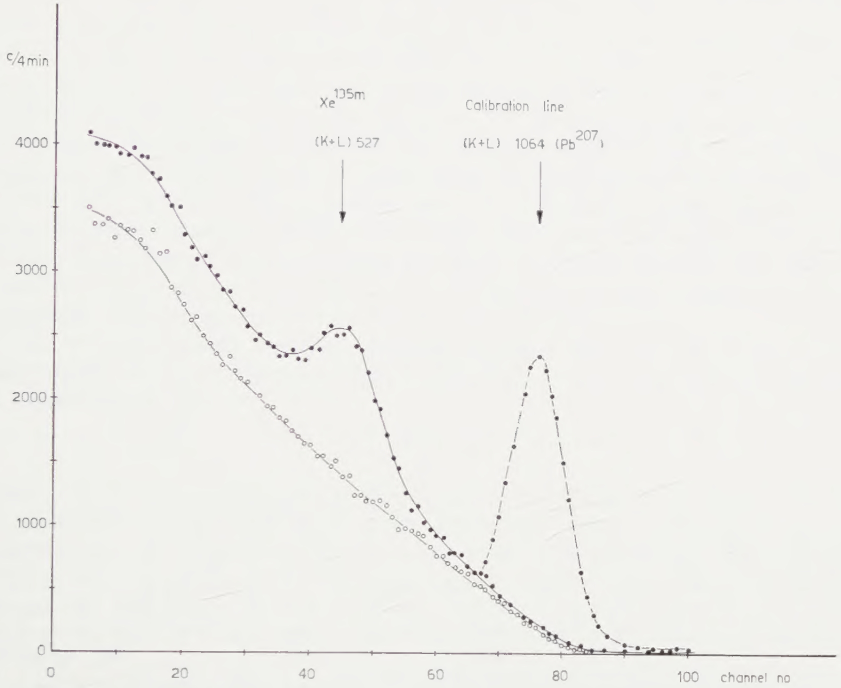

Fig. 6. An electron scintillation measurement on an isotope separated $Xe^{135m} + Xe^{135}$ sample. (K + L) conversion electrons from the 1064 kev transition in Pb^{207} are used for calibration.

energy of a possible β-branching to a low lying level in Cs^{135} must be of the order of 1.5 MeV, which should be well resolved from the maximum β energy from the ground state in Xe^{135}. This was investigated by a scintillation spectrometer measurement using a plastic crystal and the 100 channel pulse-height analyzer to register the electrons. Fig. 6 shows such a measurement.

For energy calibration a Bi^{207} sample was used. The dashed line in Fig. 6 represents the $(K + L)$ conversion electrons of the γ energy 1064 keV. The curve with filled points is due to a newly isotope separated sample, while the curve with open points is taken about 2 hours later. At an energy of about 500 keV is seen the 15 min. $M4$ transition. No other components which could be ascribed to the $h_{11/2}$ level are seen, however. It seems therefore legitimate to state that a competing β-branch to the 527 keV γ-ray is less than about 10 %. A more careful investigation of the β-spectrum with special emphasis on low-lying energies seems, however, necessary in order to estimate the β-branching completely.

Energy measurement

The energy of the $M4$ transition was measured in a double focusing β-spectrometer [15]. In Fig. 7 are seen the K and L conversion electron lines when a sample prepared by procedure (A) was used. The resolution was in this investigation set to about 0.7 %. The decay of the lines was followed, showing that they could be assigned to the 6.7h I^{135}.

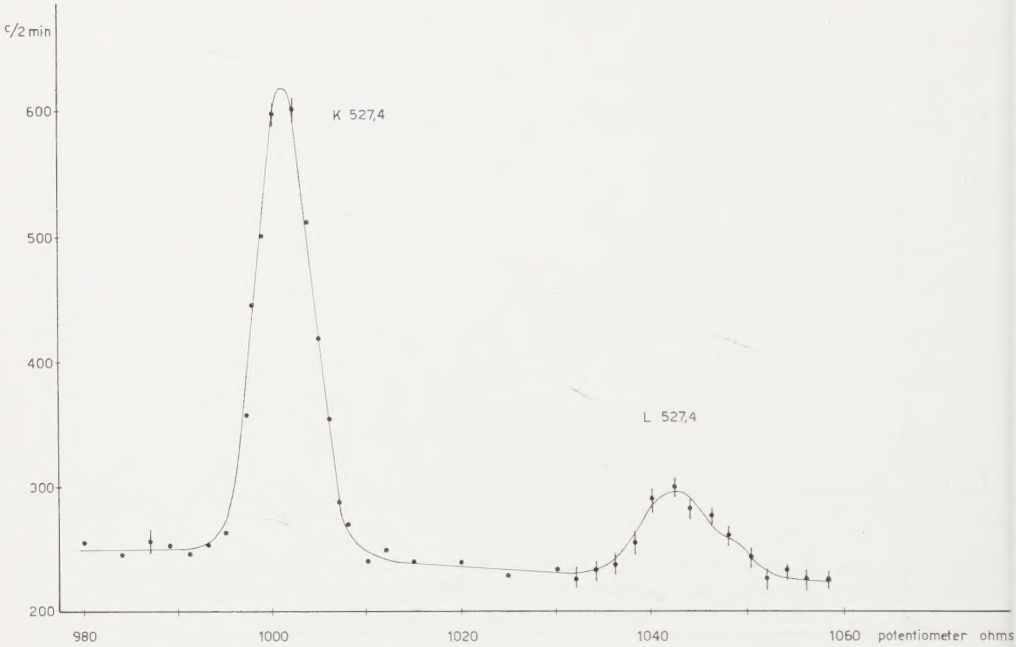

Fig. 7. Conversion lines of the isomeric γ-ray of Xe^{135m} measured with a resolution of 0.7 %. The source is isotope separated I^{135}.

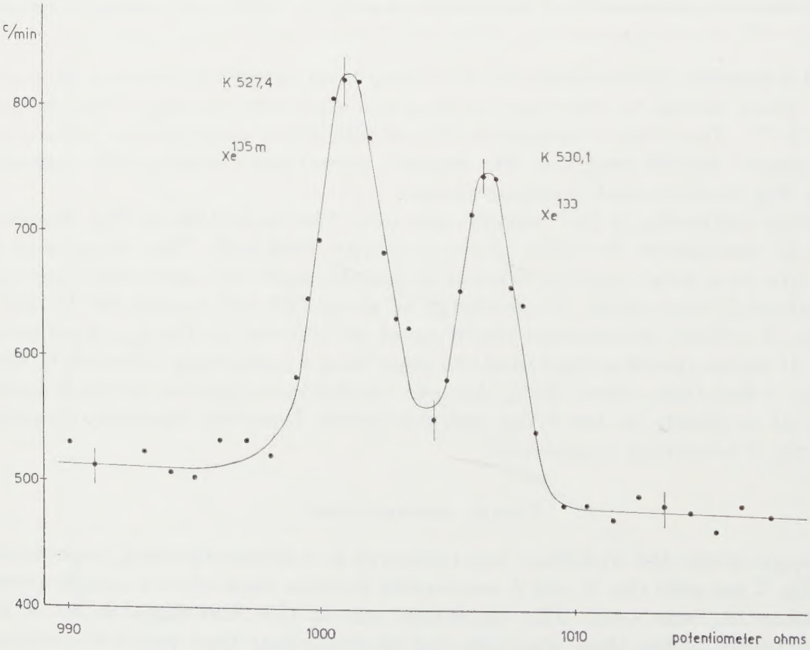

Fig. 8. Conversion lines of Xe^{135} and Xe^{133} measured with a resolution of 0.3 % and using a not isotope separated sample of iodine.

As a comparison to Fig. 7, a measurement on a not isotope separated iodine sample is given in Fig. 8. The resolution is here about 0.3 %. The decay of the two peaks showed that the one with the lower energy should be due to the isomeric state, while the other was probably due to the decay of I^{133}. In order to avoid the escape of the Xe^{135m} from the sample, a thin foil was in some cases placed over the activity as mentioned above. This caused a small shift in the position of the lines. When no foil was used only the higher energy peak was observed, which therefore could be used as an energy standard for the $M4$ energy. That the high energy could be observed without the foil must be due to the fact that the decay time of the state in Xe^{133} giving the energy is short in comparison with the escape time of the Xe isotope from the sample. This is, however, not the case for Xe^{135m}.

Even if the intensity relation between the two peaks in Fig. 8 is uncertain, an energy estimation is in fact possible. From Figs. 7 and 8 one finds the energy of the $M4$ transition to be

$$E_\gamma = 527.4 \pm 0.8 \text{ keV}.$$

The β-spectrometer was energy calibrated by using the K 569.7 keV line in Pb^{207}. The observed energy value is in good agreement with that found in the γ-energy measurement. It is, however, larger than that used earlier [7] to calculate the empirical matrix element of the transition, which therefore is reduced considerably.

From the two peaks K and L in Fig. 7, the ratio K/L could be estimated. It is found to be 5.8 ± 1.1. To obtain this value it was necessary to correct for the admixture of M conversion electrons in the L conversion peak. This was done by using the theoretical L/M ratio. This is relatively insensitive to different multipolarities of the kind present here. Rose [16] gives for L/M a ratio 2.1. The uncertainty of the measured points in Fig. 6 made it difficult to use the experimental values. The theoretically predicted ratio can, however, be too small by about 50 %, which has been observed by several authors for other transitions [cf. e.g. 17]. This effect should mainly be due to the fact that the screening is not included in the calculated values of M conversion coefficients. This could, in the present case mean that the K/L ratio should decrease to 5.3. The observed value indicates, however, in both cases an $M4$ transition as seen from the tabulated K/L ratio. For an $M4$ transition K/L is 5.2 while for $E4$, which could also be possible from the point of view of the half-life of the state, is 3.7. The assignment is, of course, also strongly suggested by the α_K measurement.

The empirical matrix elements of the $M4$ isomers in Xe

In table 1 the energies and the observed half-lives ($T_{1/2}$) of the isomeric transitions of $M4$ type in the four odd Xe-isotopes Xe^{135}, Xe^{133}, Xe^{131} and Xe^{129} are summarized. The mean life τ_γ of the γ-ray obtained from $T_{1/2}$ and internal conversion data are also tabulated. For Xe^{135m} the values are those measured in this investigation, while the other mainly are taken from [7] after small adjustment. The half-lives of the Xe isomers 131 and 129 have, however, been reinvestigated. The only deviation from earlier data was found in Xe^{129m}, in which a 10 % longer half-life was measured.

In the last column of Table 1 the values of the square of the empirical matrix element (M) are given. These are obtained from the expression for the transition probability (ω_γ) of the electromagnetic radiation of the $M4$ type as given by [1, 2].

$$\omega_\gamma = \frac{1}{\tau_\gamma} = C(M\,L) \cdot A^2 \cdot E_\gamma^9 \cdot S \cdot M^2 \tag{2}$$

where

$C(M\,L)$ = a constant, $1.81 \cdot 10^{-6}$ in the present case
τ_γ = mean life of the transition in sec.
A = mass number
E_γ = energy of the $M4$ γ-ray in MeV
S = statistical factor, in this case 15/11
M = radial matrix element.

Table 1. Isomeric transitions of $M4$ type in Xe-isotopes.

Isomer	Transition energy (MeV)	Observed half-life	Mean life ($\tau\lambda$ sec)	M^2
Xe^{135m}	0.5274 ± 0.0008^a	15.8 ± 0.4 min[a]	$(1.67\,^{+0.25}_{-0.06}) \cdot 10^{3a}$	$4.2^{+0.3}_{-0.7}$
Xe^{133m}	0.2328 ± 0.0003	$2.2 \pm 0.1\ d$	$(2.88 \pm 0.22) \cdot 10^6$	4.0 ± 0.4
Xe^{131m}	0.1636 ± 0.0003	$12.0 \pm 0.2\ d^a$	$(7.51 \pm 0.37) \cdot 10^7$	3.7 ± 0.3
Xe^{129m}	0.1966 ± 0.0006	$8.9 \pm 0.2\ d^a$	$(2.42 \pm 0.14) \cdot 10^7$	2.3 ± 0.2

[a] This work. Other data from [6, 10].

The theoretical value of M^2 as calculated from single particle assumptions is 10.8 [2]. This is for a neutron transition i.e. a transition in which a neutron should be responsible for the single particle transition. It can, however, be pointed out that the above mentioned calculations by K. K. Gupta and R. D. Lawson [4] in which a weak configuration mixing is taken into account, gives a reduction of the theoretical matrix element of about 25 % for a transition of the kind discussed here. This would therefore give a value of the theoretical M^2 equal to about 8. This should then be compared to the empirical value of M^2, which is obtained from (2) by using the observed values of A, E_γ and τ_γ.

Table 1 indicates now that the empirical M^2 values for the three first Xe isomers are in fact equal within the experimental errors. The M^2 of Xe^{129m} is, however, somewhat lower than the others. It can be noted that this deviation of the matrix element for Xe^{129} has a parallel in the l-forbidden $M1$ transition in the same isotope. The transition probabilities for this shows a deviation of a factor of about 2.5 in comparison to other similar cases in neighbouring isotopes [18].

The constancy of the values of M^2 is in contradiction to what was stated in an earlier work on this subject [7], in which a small increase of the empirical matrix element in Xe-isotopes close to the neutron number $N = 82$ was observed. This was mainly due to the energy of the γ-ray used for Xe^{135} which was (0.51 ± 0.01) MeV. However, the newly measured energy decreased the M^2 value by about 25 %, which thus is the main reason why the M^2 value of Xe^{135} is now equal with the other two Xe isomers.

In the error of the empirical matrix element for Xe^{135} is incorporated the uncertainty of the magnitude of the β-branch, which according to the measurements discussed above could be limited to be less than 10 %. Such a large figure is not used for the other isomers, in which a β-branch less than 2 % is assumed. In the decay of Xe^{129m} and Xe^{131m} it is unlikely that a notable β-branch can occur but for the $h_{11/2}$ level in Xe^{133} a redetermination should be made. Also a more careful study of the purity of the multipolarity of the $h_{11/2} \rightarrow d_{3/2}$ transition in all the four Xe isomers is desirable. It should be observed that in the calculations of the empirical matrix element in Table 1 it is assumed that the transitions are of pure $M4$ type and that theoretical values of α_K is used. The uncertainty of the α_K found experimentally are relatively large. For the isomers 133, 131 and 129 α_K is 4.4 ± 1.4, 29 ± 4 and 11 ± 4 [21]. If these are taken into account in the errors of M^2 these will increase considerably. This is so because a large value of α_K contributes strongly to the magnitude of M^2.

The theoretical value for the radial matrix element given above is in principle valid only for transitions between states containing one particle or hole [cf. e.g. 2]. In other cases, even if the wave functions of the states are pure, independent particle wave functions, the transition probabilities between states of partially filled orbits is less than that between corresponding single particle states. This reduction arises because a fraction of the m-substates, which would be available to the particle in the corresponding transition between single particle states are not available in this case to the transition particle because they are already occupied.

The reduced matrix element is equal to the matrix element for the corresponding transition between pure single particle states times a factor ϱ. For a transition [cf. 2].

$$[(j_a)^{2s_a+1}(j_b)^{2s_b}]_{j_a} \rightarrow [(j_a)^{2s_a}(j_b)^{2s_b+1}]_{j_b} \tag{3}$$

one has

$$\varrho = \frac{j_a + \frac{1}{2} - s_a}{j_a + \frac{1}{2}} \times \frac{j_b + \frac{1}{2} - s_b}{j_b + \frac{1}{2}}$$

while a transition

$$[(j_a)^{2s_a-1}(j_b)^{2s_b}]_{j_a} \rightarrow [(j_a)^{2s_a}(j_b)^{2s_b-1}]_{j_b} \tag{4}$$

gives

$$\varrho = \frac{s_a}{j_a + \frac{1}{2}} \times \frac{s_b}{j_b + 1}$$

In relation (3) it is assumed that the initial state with spin j_a contains $2s_a + 1$ particles in orbit a and $2s_b$ particles in orbit b and the final state with spin j_b has $2s_a$ and $2s_b + 1$ particles in orbit a and b respectively. Similar symbols are used in relation (4).

Table 2. The neutron configurations in the final and initial state in the four Xe isomers.

A	Final state			Initial state			ϱ
	$s_{1/2}$	$d_{3/2}$	$h_{11/2}$	$s_{1/2}$	$d_{3/2}$	$h_{11/2}$	
135	2	3	12	2	4	11	1
133	2	1	12	2	2	11	$\frac{1}{2}$
131	0	1	12	0	2	11	$\frac{1}{2}$
129	0	1	10	0	0	11	$\frac{1}{6}$

In table 2 the configurations for the four Xe-isomers is given. The most probable configurations are shown [19]. According to this the largest difference in ϱ is between Xe^{131} and Xe^{129} which can possibly explain the observed fact that the value of the empirical matrix element of Xe^{129} is different from the other three discussed. However, other configurations than those in Table 2 change the situation. This, together with the uncertainty of the knowledge of the magnitudes of the configuration mixing or possibly two particle transitions and collective motions in the nucleus makes it difficult to state anything definite in the present case.

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Tryckt den 14 april 1960

Uppsala 1960. Almqvist & Wiksells Boktryckeri AB